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A summary evaluation on the physical condition of soil in field experiments

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SUMMARY

A great variety of experiments are underway today to compare the impacts of different tillage systems on soil condition. In the course of our studies between 2004 and 2006 we assessed the impacts of conventional soil tillage. Our field experiments – set up in six different farms – focused on the soils' agronomical structure, penetration resistance and moisture content within the soil's physical condition in general. This paper contains a summary of the findings of the experiments and an evaluation of the impacts of conventional tillage practices on the soil's physical state in the various site conditions.

In the course of the analyses of the agronomical structure of the soils in 2004 we found statistically proven differences between the various treatments in terms of the clod fractions and the crumb fractions (LSD$_{5\%}$clod = 10.2, LSD$_{5\%}$crumb = 10.8). No significant differences were found between the dust fractions at the six sites. In the course of the analysis of its agronomical structure, the soil structure was not found to have been damaged by conventional tillage. The examination of penetration resistance showed significant differences between the various treatments in the first year of the experiments (2004) at the tillage depth (LSD$_{5\%}$20–30 = 1.2), in the second year (2005) below the tillage depth (LSD$_{5\%}$30–40 = 0.3) and in the third year (2006) in the soil's top 10 cm layer (LSD$_{5\%}$0–10 = 0.5) and in the 10–20 cm layer (LSD$_{5\%}$10–20 = 0.6). Soil penetration levels showing harmful compaction (over 3 MPa) were only found in the first year of the experiment. In terms of soil moisture content significant differences were found in 2004 in the 10–20 cm layer (LSD$_{5\%}$10–20 = 8), in the 20–30 cm layer (LSD$_{5\%}$20–30 = 7.8), in the 30–40 cm layer (LSD$_{5\%}$30–40 = 7.3) and in the 40–50 cm layer (LSD$_{5\%}$40–50 = 3.9) as well. In year 2005 significant differences were found between the treatments in the 20–30 cm layer (LSD$_{5\%}$20–30 = 1.7) and in the 30–40 cm layer (LSD$_{5\%}$30–40 = 1.9), while in 2006 no significant differences were found between the treatments in any of the relevant soil layers in terms of soil moisture content. We supplemented our experiments with the assessment of the different years' effects (impacts of the given year's weather conditions). While the different years had no significant impacts on the agronomical structure, they did influence the soils' penetration resistance and moisture contents considerably.

Under the soil and site conditions of the experiments the conventional soil tillage that had been applied for a period of three years did not result in any deterioration of the soil's physical state. In our opinion however, the positive results were more a consequence of the soils' favourable physical attributes and their favourable initial condition than the conventional tillage system applied in the experiment. For ecological and economic considerations in the longer run however, it is indispensable that soil and environment preserving tillage techniques be chosen even where the soil is in a favourable condition.

Keywords: soil condition, conventional tillage, agronomical structure, soil penetration resistance, soil moisture content.

INTRODUCTION AND A REVIEW OF LITERATURE

The most important duties of a farmer producing field crops are to protect and preserve the soil's fertility and quality, to prevent biological, physical and chemical degradation and at the same time to produce crops competitively (*Bencsik* 2009). *Pepó* (2004) held that conserving and improving, as far as possible, the physical, chemical and biological attributes of the soil are among the most essential tasks of sustainable cropping. *Várallyay* (2010) considers that mitigation of the cropping risks, soil protection, the prevention, elimination and alleviation of extreme water balance and ecological stress situations are of particular importance in "sustainable" land use. *Bartholy et al.* (2010) reported in their study that the Carpathian Basin was definitely facing a trend of warming up towards the middle of the 21st century. Hungary's annual mean temperature is expected to rise by 1.1 °C by that time. Precipitation is another key climate variable besides temperature, the variations of which also have a profound impact on the main sectors of the economy, including, in particular, agriculture. The annual average precipitation in Hungary is expected to decrease by nearly 7%. The future changes in climate factors will be forcing farmers to carefully choose soil tillage systems that are best suited to their site conditions.

The recent decades have seen a growing number of studies of the impacts of conventional and of soil protecting/preserving production methods on soils' physical conditions. The impacts of such tillage systems on the soil and on the environment have been and are still being studied by numerous Hungarian scientists (e.g. *Gyuricza* 2000, *Birkás* 2002, *Percze* 2002, *László* 2007, *Bencsik* 2009) and foreign authors (e.g. *Hill* and *Cruse* 1985, *Kladivko et al.* 1986, *Brandt* 1992, *Schwab et al.* 2002, *Turtola et al.* 2007, *Alvarez* and *Steinbach* 2009, *Cociu* 2011).

According to *Birkás* (2001) conventional farming is a target of most criticism owing to its impacts on the environment (erosion, deflation, compacting, loss of organic matter, soil, air and water pollution) and its costs. Typically monocultural land use, tillage comprising of multiple tillage passes and frequent soil disturbance leads to increased soil degradation and soil structure deterioration (*Gyuricza* 2001). Conventional tillage involves the working of the entire soil surface. Soil conditions that are considered to be favourable for plant growth are produced by more than the reasonable number of tillage passes – these practices take too much time, energy and money (*Birkás* 2001, *Birkás* 2006). As a consequence of the tillage operations entailing frequent soil disturbance, soil tillage comprising multiple tillage passes (primary tillage with ploughing in the autumn) causes soil structure deterioration and compaction (structure degradation) and a loss of organic matter (*Huzsvai et al.* 2003). A tillage and seeding system is considered to be ”soil preserving” if at least 30% of the soil surface is covered with crop residues even after seeding to protect the soil (*Dickey et al.* 1991, *Dickey et al.* 1994, *Jasa et al.* 1999, *Uri* 1999, *Birkás* 2006) and the loss of soil through erosion/deflation is reduced by at least 50% in comparison with conventional tillage (*Birkás* 2006). Adopting soil protecting and conserving tillage produces both environmental and economic benefits. The soils' physical and biological condition improves as a result of which the adverse effects of weather extremes are also alleviated. In parallel with the reduction of damage the quality of the environment also improves on the whole (*Birkás* 2006). In addition to creating and preserving favourable physical and biological conditions the application of soil conserving tillage solutions usually has a positive impact on economic factors (number of tillage passes, time and fuel requirement) (*Gyuricza* 2000). In the course of their experiments set up in Poland in 2006 and 2007 *Czyz* and *Dexter* (2008) studied the impacts of conventional and reduced tillage systems on the physical conditions of soils of two different types. They found that the tillage systems had significant impacts on the soils' physical conditions, particularly their moisture content.

According to *Husnjak et al.* (2002) discussions of conventional, soil protecting and direct seeding (no till) systems are growing increasingly important owing to ecological and economic considerations. They studied the physical attributes of a loam soil applying five different soil tillage systems (conventional, reduced, soil protecting I and II as well as direct seeding). In the course of their experiments between 1997 and 2000 they found the best physical attributes (i.e. the lowest mass per volume and the highest total porosity) in their soil in the case of the soil protecting tillage techniques.

A number of Hungarian authors examined the impacts of conventional and soil conserving tillage on the soil's physical state with the aid of penetrometers. The studies carried out by *Rátonyi* (1999) showed that the soil's physical attributes had a major impact on the growth and development of field crops. In the course of his experiments he explained the soil's penetration resistance with the aid of linear regression equations with two variables: soil moisture content and soil compaction. He found that within a given soil moisture content range the soil's penetration resistance increased towards the lower moisture content levels. In examining different tillage systems *László* (2007) found that only the top 10 cm layer of the soil was more compact in the case of direct seeding in terms of soil penetration resistance than it was after other tillage treatments. At the bottom of the tillage depths the soil resistance values measured after conventional tillage were significantly lower than after ridge tillage. Tillage caused no differences in penetration resistance below a depth of 20 cm. He explained the small soil resistance underneath the top layer after direct seeding by the favourable circumstances that developed in undisturbed soil. In the case of ridge tillage the development of a tillage pan layer was also indicated by the soil resistance value. In the case of conventional tillage he found that according to the soil penetration resistance profile, soil resistance was evenly favourable across the entire soil profile. *Gyuricza et al.* (1998) examined soil penetration with a penetrometer after five soil tillage variants (loosening + ploughing, loosening + disking, ploughing, direct seeding, disking). They found that under the given experimental circumstances the degree of soil penetration resistance had been influenced primarily by the tillage depth and the applied tillage tools. They found disking to have the most damaging impacts on the soil structure. In selecting a tillage system that equally meets the requirements of sustainable land use and cost effectiveness attention must be paid to the various tillage methods' impacts resulting in maintaining or improving the soil's structure and on its water transport regime (*Farkas* 2004).

In our six field experiments we studied the soil's agronomical structure, penetration resistance and moisture content in the circumstances of conventional tillage. This paper contains a summary of the results and findings of the soil condition studies carried out between 2004 and 2006.

Materials and methods

Geographical location

The experiments were established in 2004 in the mid-Hungarian region (Nagykáta-microregion) at six farms between Pánd (N.L. 47° 21' 01", E.L. 19° 38' 00", altitude above sea level: 129 m) and Káva (N.L. 47° 21' 19", E.L. 19° 35' 16", altitude above sea level: 131 m). The area is located in a valley surrounded by hills, but the experiments were laid out on a flat area.

Climate conditions

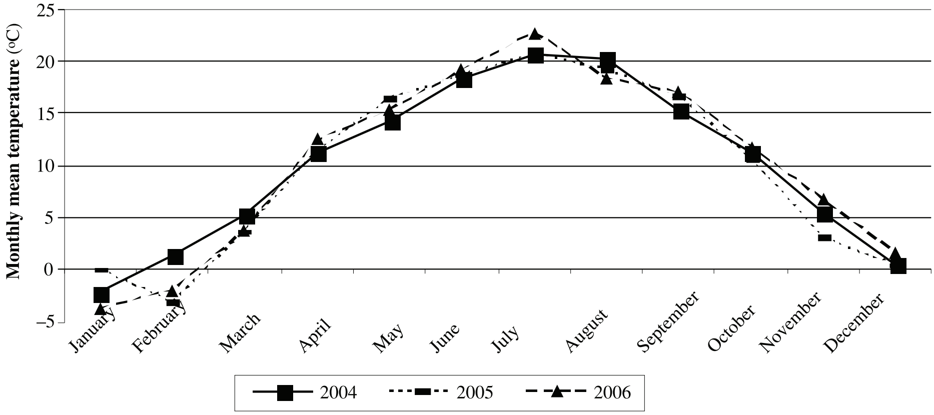

Figure 1. Changes in mean monthly temperatures (°C) in the experimental area in 2004–2006

The monthly mean temperature data (*Figure 1.*) were measured at an automated meteorological station in the nearby Tápiószele Institute for Agrobotany. The annual mean temperature averaged over three years was 10.09 ^{o}C (with a maximum monthly mean of 21.43 ^{o}C in July and a minimum of –1.97 ^{o}C in January). The lowest mean annual temperature values (9.81 ^{o}C) were recorded in 2005.

Precipitation data were obtained from a recording station in Nagykáta. Averaged over three years the highest monthly precipitation was recorded in June (71.20 mm) and August (99.43 mm) and the lowest (19.50 mm) in October. The highest annual precipitation (702.1 mm) in the three years was received in 2005 (*Figure 2.*).

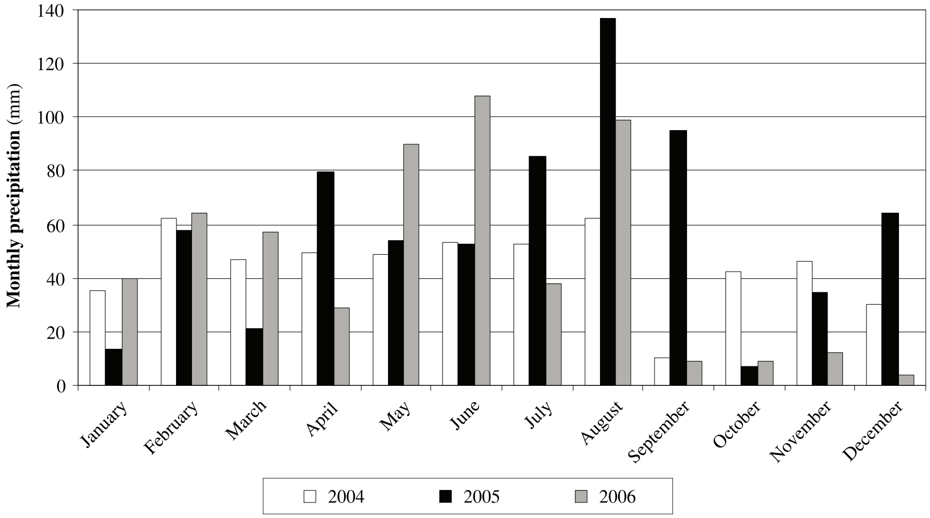

Figure 2. Monthly precipitation (mm)
in the experimental area in 2004–2006

Soil parameters

Since no soil tests had previously been performed on the pilot farm, samples from the six experimental sites were examined for upper limit of plasticity (KA), pH_{KCL} value, calcium carbonate, humus, phosphorus and potassium contents under laboratory conditions using standard procedures between 2004 and 2006. Based on the values obtained for KA (37–39 over the three-year period) soil texture was estimated to be loam. The pH of the examined soils varied from slightly acidic to neutral (pH_{KCL} = 5.70–7.22). The humus content in the top soil was poor (1.26–2.75%) while the AL-P_2O_5 content was 65.79–229.97 ppm and the AL-K_2O content 61.80–396.59 ppm.

The agronomical structure, penetration resistance and soil moisture content were examined during the field experiments under conventional tillage conditions. Conventional tillage is characterized by high traffic throughput, involving time- and energy-consuming operations.

The tillage depth is more frequently adjusted to the needs of the plants and the tools at hand than to the moisture or compactness of the soil. Crop residues are not utilized outside the growing period to protect and cover the soil surface, thus minimizing moisture loss (*Birkás* 2002). A friable seedbed free of crop residues is seen as desirable for conventional tillage. In the field experiments the same tillage systems were used for post-harvest operations in all three years: disking the upper layer was followed by autumn ploughing (30 cm). In spring, before sowing, the soil was loosened with a cultivator. Maize (*Zea mays* L.) and sunflower (*Helianthus annuus* L.) were grown on the farms during the three-year period. The crop sequences in the experimental treatments were as follows: Experiment A: maize-sunflower-maize, Experiment B: maize-sunflower-maize, Experiment C: maize-maize-sunflower, Experiment D: maize-maize-maize, Experiment E: maize-maize-sunflower, Experiment F: maize-maize-maize.

Agronomical structure

In the field experiments the agronomical structure of soil was assessed by dry sieving. On the six farms the clod fraction was determined twice in 2004, three times in 2005 and 2006 with three parallel determinations each year. The soil samples, collected from the experimental area, were dried to constant weight, and fractioned by 7 sieves of different pore sizes (20, 10, 5, 3, 1, 0.5 and 0.25 mm) to 8 different size-fractions. The weights of the certain fractions were determined and expressed as a mass percentage of the sample. Thus we obtained the percentage clod, crumb and dust composition of soil. When evaluating the agronomical structure of soil, the shape of the structural elements is not considered. Only by their sizes are they classified and the proportions of the aggregates, falling to certain size-ranges, are determined (*Stefanovits* 1992). Thus the retained fraction on sieves with not less than 10 mm pore size fall to clod fraction (10 mm <), the ones with 0.25–10 mm pore size belong to crumb fraction (0.25–10 mm), while the ones passing through the 0.25 mm pore size sieve to the dust collector represent the dust fraction (0.25 mm >).

Penetration resistance (PR), soil moisture

PR measurement (one of the most commonly used measurements for compaction) was used for the examination of the compacted layers. The changes in the physical properties of soil in space and time are well demonstrated if the soil moisture content is also considered for the soil penetration resistance. A mechanical, spring-penetrometer was applied to the field experiments in the vegetation period. The measurements were carried out on three replicates, at 10 cm intervals to a depth of 50 cm (*Daróczi* and *Lelkes* 1999). The determination of the soil moisture content was carried out simultaneously with the PR. The moisture content of the soil samples was determined by an oven method, drying at 105 ^{o}C, until a constant weight was achieved. Similarly to the practice applied for PR determination, samples for soil moisture determination were taken at 10 cm intervals to 50 cm depth in three replicates. The agronomical structure, PR and moisture content measurements were evaluated by a Microsoft Office Excel-program. Single factor analysis of variance was applied for the statistical evaluation (*Sváb* 1981, *Baráth et al.* 1996).

RESULTS AND DISCUSSION

The relative proportions of the various soil aggregate fractions in soils under different tillage treatments were already discussed in earlier papers (*Földesi* and *Gyuricza* 2011a) and studies of soil penetration and soil moisture between treatments have also been covered in detail (*Földesi* and *Gyuricza* 2011b). Moreover, our statistical analyses were supplemented with studies of the impacts of specific years, i.e. with comparisons of averages of measured variables across different years (*Földesi* and *Gyuricza* 2012). This paper contains a summary and evaluation of the findings of various soil condition studies along with comparisons to data found in literature.

Assessment of the agronomical structure

The soils' agronomical structures were established in the course of the growing season twice in 2004 and three times in both 2005 and 2006, in three iterations on each occasion, by sifting the dry soil. What was studied during the three years of our experiment was how the relative proportions of the clod, the crumb and the dust fractions were changing as a consequence of conventional soil tillage under field conditions. In 2004 we found statistically significant differences between the different treatments in terms of the clod fraction and the crumb fraction which is the most important component of the soil for the purposes of tillage ($LSD_{5\%}clod = 10.2$, $LSD_{5\%}crumb = 10.8$). No significant differences were found between the treatments in terms of the dust fraction. In 2005 and 2006 however, no significant differences were found between the six experiments in terms of any of the soil aggregate fractions. In assessing the agronomical structure of the soil no damage was found in the soil structure after conventional tillage. *Birkás* and *Gyuricza* (2004) found that in soils that frequently disturbed by ploughing and disking there were smaller crumb fractions and higher proportions of dust and clods. Monotonous land use may, over time, lead to the strengthening of degradation processes which cause deterioration in the soil structure. In our experiment the ratio of the crumb fraction that is so crucial for cropping did not drop below 70% even by the third year of our studies. *Bencsik* (2009) studied the soil's agronomical structure under conventional and ridge tillage as well. In view of the impacts of the treatments she found significant differences in terms of the clod and the crumb fractions, i.e. ridge tillage was found to be more favourable in general for the soil's structure than conventional tillage based on ploughing.

To improve the accuracy of our conclusions we supplemented our experiment by studying the effects of the various years as well. A single factor variance analysis process was carried out to statistically confirm the differences between the years of our experiments, in the course of which the averages of the percentages of the various soil aggregate fractions measured in the given years were taken into account. No significant differences were found between the years concerned in any one of the fractions. The proportion of the clod fraction was highest in 2004 but even then we found no heavy clod forming. During the years of our experiments and in view of all of the treatments on the whole, the highest ratio of the crumb fraction, which is the most favourable component for cropping (as an average of the values measured in the case of the different treatments) was found in 2005. *Figure 3.* shows the changes in the agronomical structure as a percentage of the three years (2004–2006).

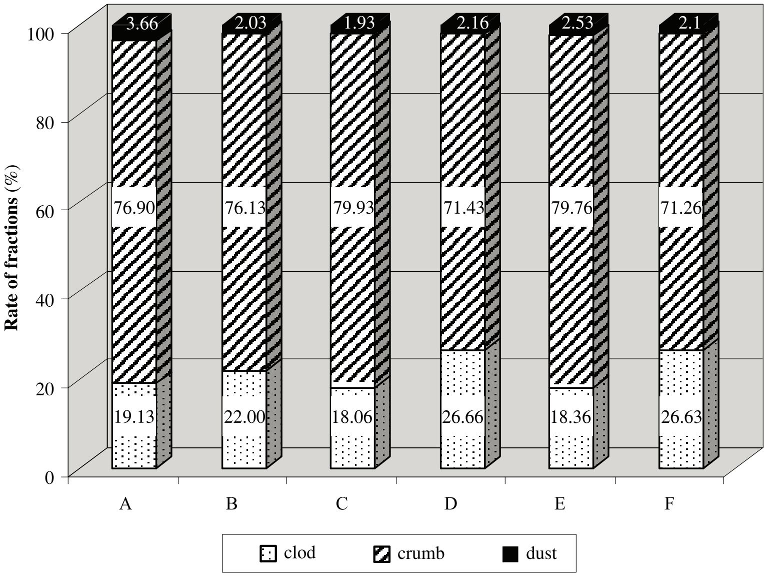

Figure 3. Changes in the agronomical structure in the experimental area in 2004–2006

Soil penetration resistance assessments

In the course of the growing season – simultaneously with the assessments of the agronomical structure – we measured soil penetration resistance (PR) twice in 2004 and three times in 2005 and 2006 each (*Figure 4.*).

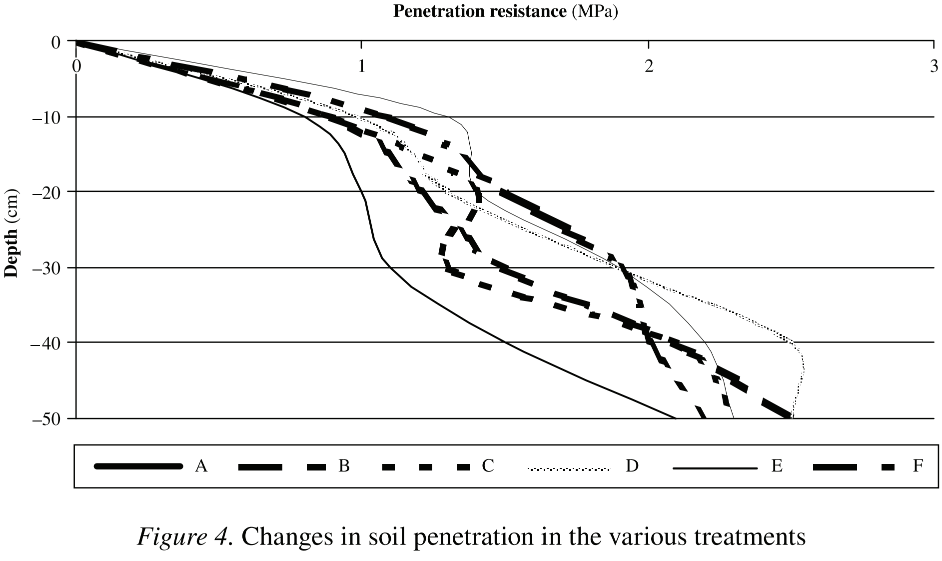

Figure 4. Changes in soil penetration in the various treatments as an average of the tree years (2004–2006)

In the course of the six field experiments in the assessment of PR in the first year (2004) we found significant differences (LSD$_{5\%}$20–30 = 1.2) between the treatments in the tillage depth (i.e. in the 20–30 cm layer). In the second year (2005) significant differences were found underneath the tillage depth, i.e. in the 30–40 cm layer (LSD$_{5\%}$30–40 = 0.3), while in the third year (2006) significant differences were found between the treatments in the top 20 cm layer (LSD$_{5\%}$0–10 = 0.5, LSD$_{5\%}$10–20 = 0.6). PR values (over 3 MPa) indicating harmful compaction were only found in the first year of the experiment and only in treatment A (40–50 cm), treatment B (30–40 and 40–50 cm) and treatment E (40–50 cm layer). The averages of the soil PR values measured in 2005 and 2006 did not reach the limit of harmful compaction in any one of the experiments. This was a definitely positive result from the aspect of cropping because during the rainy year of 2005 and thereafter the movement of rainwater into the soil and the utilisation of the water in the soil was not impeded by compact layers at any depth in the soil.

The assessments of PR during the years of the experiments between the treatments were supplemented by comparing the averages of the data measured in the different years across the years concerned. Significant differences were found between the years at every depth (LSD$_{5\%}$0–10 = 0.2, LSD$_{5\%}$10–20 = 0.2, LSD$_{5\%}$20–30 = 0.2, LSD$_{5\%}$30–40 = 0.2, LSD$_{5\%}$40–50 = 0.2), showing that the different years' impacts did have a substantial effect on the PR values. *Mikó* (2009) arrived at similar conclusions in the course of his experiments with green manure plants and he found that the PR levels were closely correlated to the years' impacts and the site conditions. In studying three soil tillage techniques (ploughing in the autumn, ploughing in the spring and shallow disking in the spring) *Rátonyi* (1999) found that PR increased in the tilled layer together with the increasing depth in each treatment and the maximum values were measured in the compact layers (so-called plough pan and disk pan) formed as a consequence of tillage to the same depth year after year. In the course of our PR assessments no plough pan or disk pan layer could be found at the depth of tillage by the third year of our experiments.

Soil moisture studies

In assessing the soil's physical condition its moisture content was also established – simultaneously with the assessments of agronomical structure and PR – twice in 2004 and three times in 2005 and 2006 each (*Figure 5.*).

The soil's moisture content varies greatly in both space and time (*Stefanovits* 1992). Significant differences were found between the treatments in the first year of the experiments (2004) in the 10–20 cm layer (LSD$_{5\%}$10–20 = 8), in the 20–30 cm layer (LSD$_{5\%}$20–30 = 7.8), in the 30–40 layer (LSD$_{5\%}$30–40 = 7.3) and in the 40–50 cm layer (LSD$_{5\%}$40–50 = 3.9) alike. Apart from the 20–30 cm layer in the various soil layers the lowest soil moisture content was always found in treatment B from among the six treatments applied in the experiment. The increase in PR must have been caused by the low soil moisture contents measured in the 30–40 cm and the 40–50 cm layers. *Rátonyi* (1999) used a penetrometer combined with a soil moisture content meter for the assessment of the physical condition of the soil. He found that in the soil moisture content range of his experiments that the lower the soil moisture content the higher the PR was.

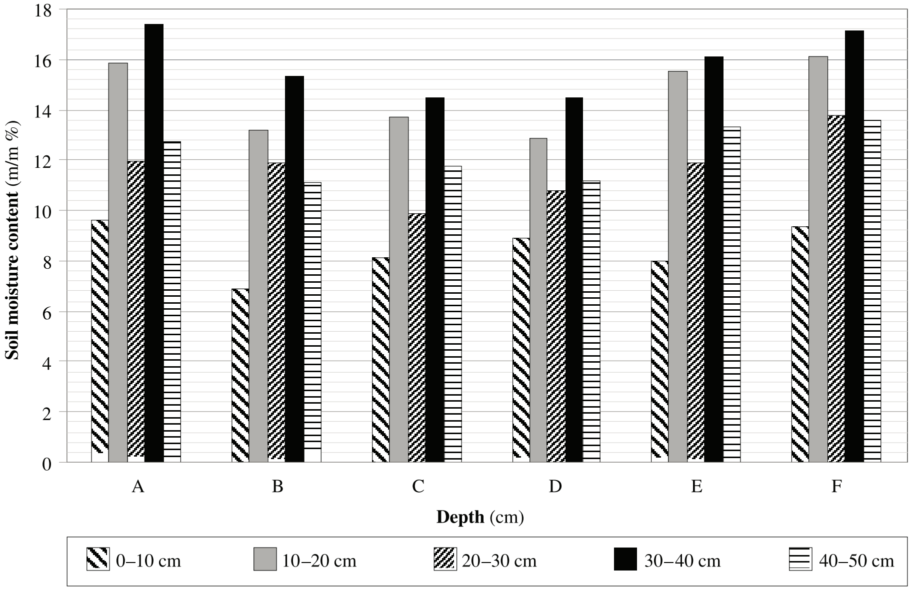

Figure 5. Changes in soil moisture contents after the different treatments as an average of the three years (2004–2006)

In 2005 significant differences were found between the treatments in the 20–30 cm layer ($LSD_{5\%}20–30 = 1.7$) and in the 30–40 cm layer ($LSD_{5\%}30–40 = 1.9$). No significant difference was found between the treatments in 2006 in any one of the different soil layers in our assessments of the soil moisture content.

The assessments between treatments were supplemented by comparing the averages of the data measured in the various years across the different years of the experiment. Apart from the 10–20 cm depth, significant differences were found in each layer ($LSD_{5\%}0–10 = 0.8$, $LSD_{5\%}20–30 = 1$, $LSD_{5\%}30–40 = 1$, $LSD_{5\%}40–50 = 0.9$), i.e. the effects of the different years could be identified in these soil layers as well. The years' impacts affected not only PR but also – except for the 10–20 cm layer – the soil moisture content. Similar conclusions were drawn by *Mikó* (2009) as well, who found in the course of his experiments that soil moisture content also depends heavily on year and site.

In the course of their soil condition assessments *Beke et al.* (2007) concluded that in a given site and under a given type of tillage PR is closely correlated with the amount of precipitation landing on the soil surface and consequently with the soil's moisture content. *László* (2007) assumed that the amount of precipitation has a massive impact on the effects of tillage systems on soil attributes.

The only significant differences between the treatments were found in the 10–20 cm layer ($LSD_{5\%}10–20 = 1.7$). At that depth the soil's moisture content depended not only on the year's impacts but also on the applied agricultural technology. Accordingly, conventional tillage affected the soil's moisture content in the 10–20 cm layer. The soil's moisture content dropped below 40 cm in each treatment in years 2005 and 2006. Our findings are in accordance with the findings reported in literature (*Beke* 2006, *László* 2007, *Mikó* 2009), in that PR and soil moisture are both heavily affected by the different year's impacts.

CONCLUSIONS AND RECOMMENDATIONS

Within the soil's physical state in general, our field experiments were focused on the soils' agronomical structure, penetration resistance and moisture content. The findings of the studies of physical soil condition between 2004 and 2006 lead us to conclude that the applied conventional tillage techniques did not result in any degradation in the soils' physical condition by the last year of the experiment. No harmful clod forming was found by the assessment of the soil's agronomical structure, which was probably a result of the high quality of ploughing which was carried out in the optimum soil moisture range from the aspect of tillage. Since however, land use affects the soil's structure over time, tillage repeatedly carried out in the same depth year after year increases the risks of the formation of compact layers in the soil, therefore there is a case for the application of soil structure conserving tillage techniques and for varying the tillage depth between any two years.

No plough or disk pan layer could be found even by the third year of our soil penetration resistance tests at the depth of tillage. Thus there was no impenetrable compact layer that could have prevented the movement of rainwater into the soil and then down to deeper soil layers, which is one of the key factors affecting the success of cropping. We found that the different years heavily affected the soil's penetration resistance and moisture content values. Soil moisture content in the 10–20 cm layer was affected not so much by the different years but by the applied technologies. Consequently, the impacts of conventional soil tillage on the soil's moisture content were confirmed in this soil layer as well.

Summing up the findings of our soil condition assessments we concluded that the applied soil tillage did not, under the soil and site circumstances of our experiments, result in any degradation of the soil's physical condition. Nonetheless, we hold that the positive findings were more heavily influenced by the soil's favourable physical conditions and the favourable initial soil condition than the applied conventional tillage techniques. Over a longer term however, from ecological and economic aspects, the adaptation of soil and environment preserving methods suited to the prevailing site conditions is an indispensable requirement even in the case of favourable soil conditions.

A talaj fizikai állapotának összegző értékelése szántóföldi kísérletekben

FÖLDESI PETRA – GYURICZA CSABA

Szent István Egyetem
Növénytermesztési Intézet
Gödöllő

ÖSSZEFOGLALÁS

Napjainkban világszerte számos kísérlet folyik a különféle művelési rendszerek talajállapotra gyakorolt hatásának összehasonlítására. 2004–2006 között elvégzett vizsgálataink során a hagyományos talajművelés hatását tanulmányoztuk. A hat gazdaságban beállított szántóföldi kísérleteink a talaj fizikai állapotán belül az agronómiai szerkezetre, a talaj ellenállására és nedvességtartalmára fókuszáltak. Jelen dolgozatban az elvégzett vizsgálatok eredményeit összegezzük, és azok alapján értékeljük adott termőhelyi körülmények között a hagyományos művelés hatását a talaj fizikai állapotára.

Az agronómiai szerkezet vizsgálata során 2004-ben a rögfrakció és a morzsafrakció esetében találtunk igazolható statisztikai eltérést az egyes kezelések között (SzD$_{5\%}$rög = 10,2, SzD$_{5\%}$morzsa = 10,8). A porfrakciók között nem volt szignifikáns különbség. A 2005. és 2006. években egyik frakcióméretnél sem találtunk szignifikáns eltérést a hat beállított kísérlet között. A talaj agronómiai szerkezetének vizsgálatakor a hagyományos művelés során nem tapasztaltuk a talajszerkezet károsodását. A talajellenállás vizsgálatakor az első évben (2004) a művelés mélységében (SzD$_{5\%}$20–30 = 1,2), a második évben (2005) a művelés mélysége alatt (SzD$_{5\%}$30–40 = 0,3), a harmadik évben (2006) a talaj 0–10 cm-es (SzD$_{5\%}$0–10 = 0,5) és 10–20 cm-es (SzD$_{5\%}$10–20 = 0,6) mélységében találtunk szignifikáns eltérést a kezelések között. Csak a kísérlet első évében tapasztaltunk káros tömörödésre utaló (3 MPa feletti) értéket. A talaj nedvességtartalmának vizsgálatakor 2004-ben a 10–20 (SzD$_{5\%}$10–20 = 8), a 20–30 (SzD$_{5\%}$20–30 = 7,8), a 30–40 (SzD$_{5\%}$30–40 = 7,3) és a 40–50 cm-es mélységben (SzD$_{5\%}$40–50 = 3,9) is szignifikáns különbséget találtunk. A 2005. évben a 20–30 cm-es (SzD$_{5\%}$20–30 = 1,7) és a 30–40 cm-es (SzD$_{5\%}$30–40 = 1,9) mélységben találtunk szignifikáns különbséget a kezelések között. A 2006. évben egyik mélységben sem találtunk szignifikáns eltérést a kezelések között a nedvességtartalom vizsgálatakor. Eredményeinket az évjárathatás vizsgálatával is kiegészítettük. Míg az agronómiai szerkezetre nem volt hatással az évjárat, addig a talaj ellenállását és nedvességtartalmát nagymértékben befolyásolta.

A vizsgált talaj- és termőhelyi viszonyok között a három éven keresztül alkalmazott hagyományos talajművelés a vizsgálat utolsó évére nem eredményezte a talaj fizikai állapotának leromlását. Véleményünk szerint azonban a pozitív eredmények alakulásában a talaj kedvező fizikai tulajdonságai és a kedvező kiindulási talajállapot nagyobb mértékben játszott szerepet, mint az alkalmazott hagyományos művelési rendszer. Hosszú távon azonban ökológiai és ökonómiai megfontolásból még kedvező talajállapotnál is elkerülhetetlen az adott termőhelyi adottságokhoz igazodó talaj- és környezetkímélő módszerek adaptálása.

Kulcsszavak: talajállapot, hagyományos talajművelés, agronómiai szerkezet, talajellenállás, talajnedvesség.

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